



Some creative applications of circular economy  
principles in research  
^  
materials

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Director, Institute for Frontier Materials, Deakin University

# Institute for Frontier Materials



Staff Numbers\*

**233**  
Total Staff

**159**  
Academic

**74**  
Professional

\*Headcount



**177**  
HDR students



Students from  
**30**  
Countries



Partnerships

**200**  
Industry Partners  
across  
**15**  
Countries

- Advanced Alloys and Structural Materials
- Fibres and textiles
- Carbon fibres and textiles
- Energy and Electro-materials



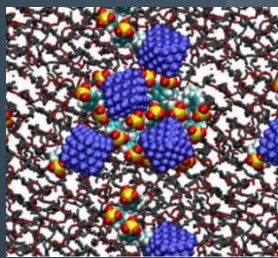
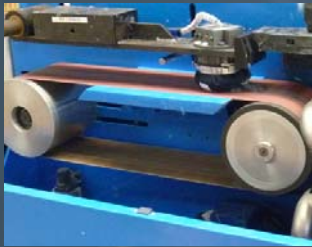
# Cultivating a material innovation ecosystem that explicitly considers social responsibility

## Exploration

characterizing



experimenting



modelling

## Realization

FormFlow



Carbon Nexus



MOTOCAP



BatTRI Hub

## Circulation



Circular Denim



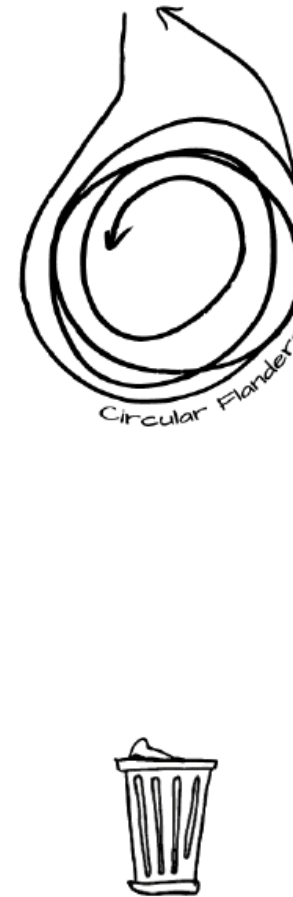
LINEAR ECONOMY




RECYCLING ECONOMY



CIRCULAR ECONOMY



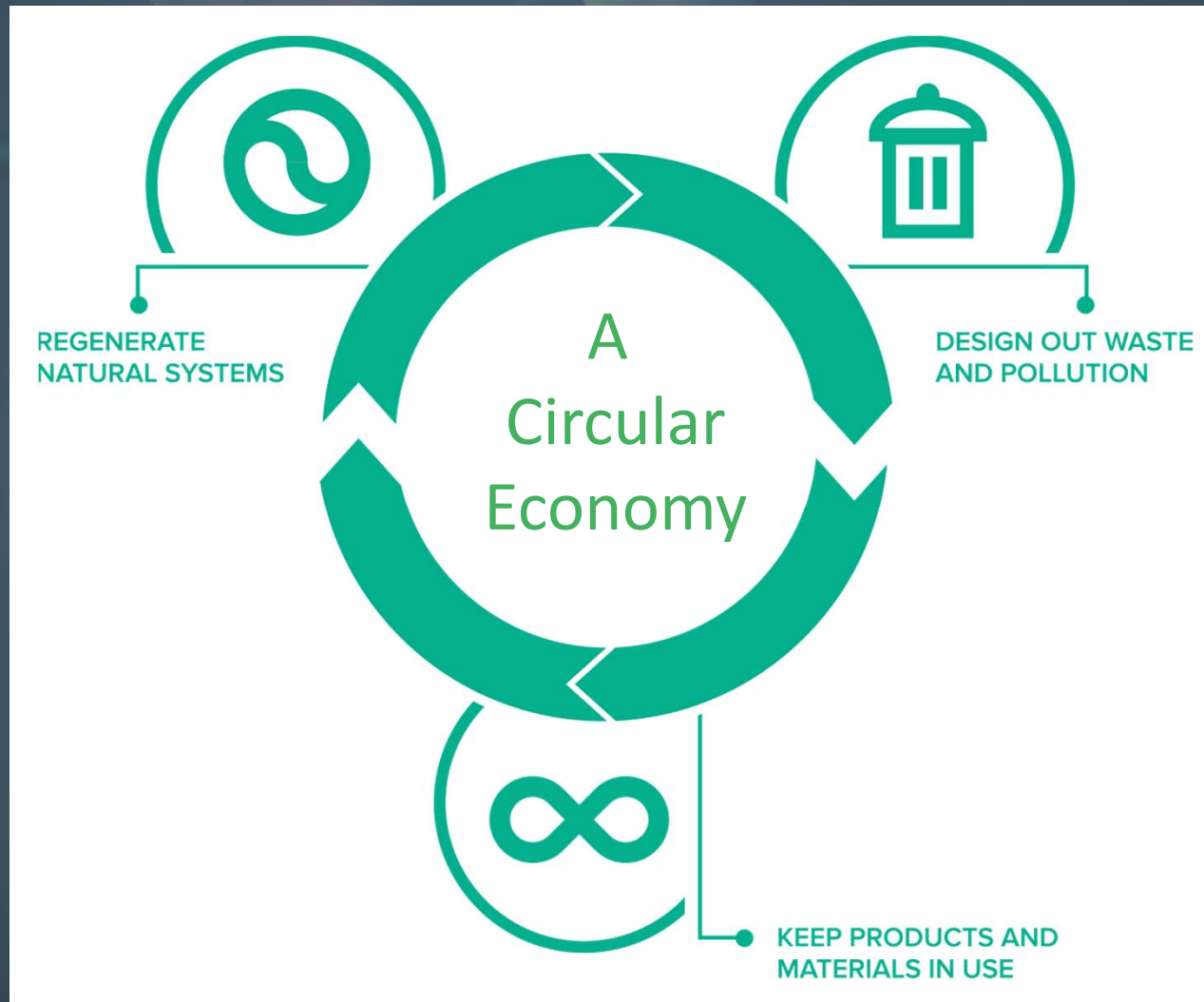




“A circular economy...aims to keep products, components and materials at their highest utility and value, at all times.”

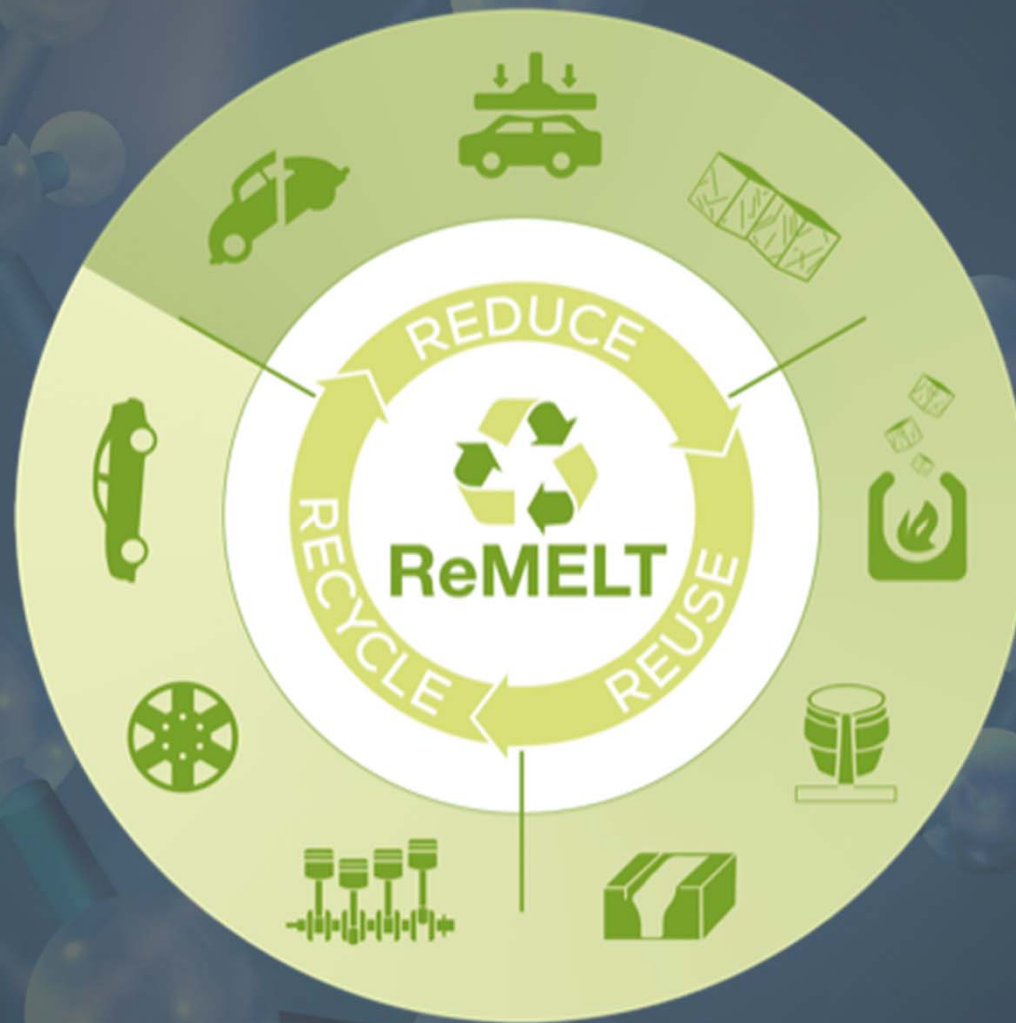
Ken Webster  
The Circular Economy: A wealth of flows

# 3 high level principles of a circular economy



<https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy>

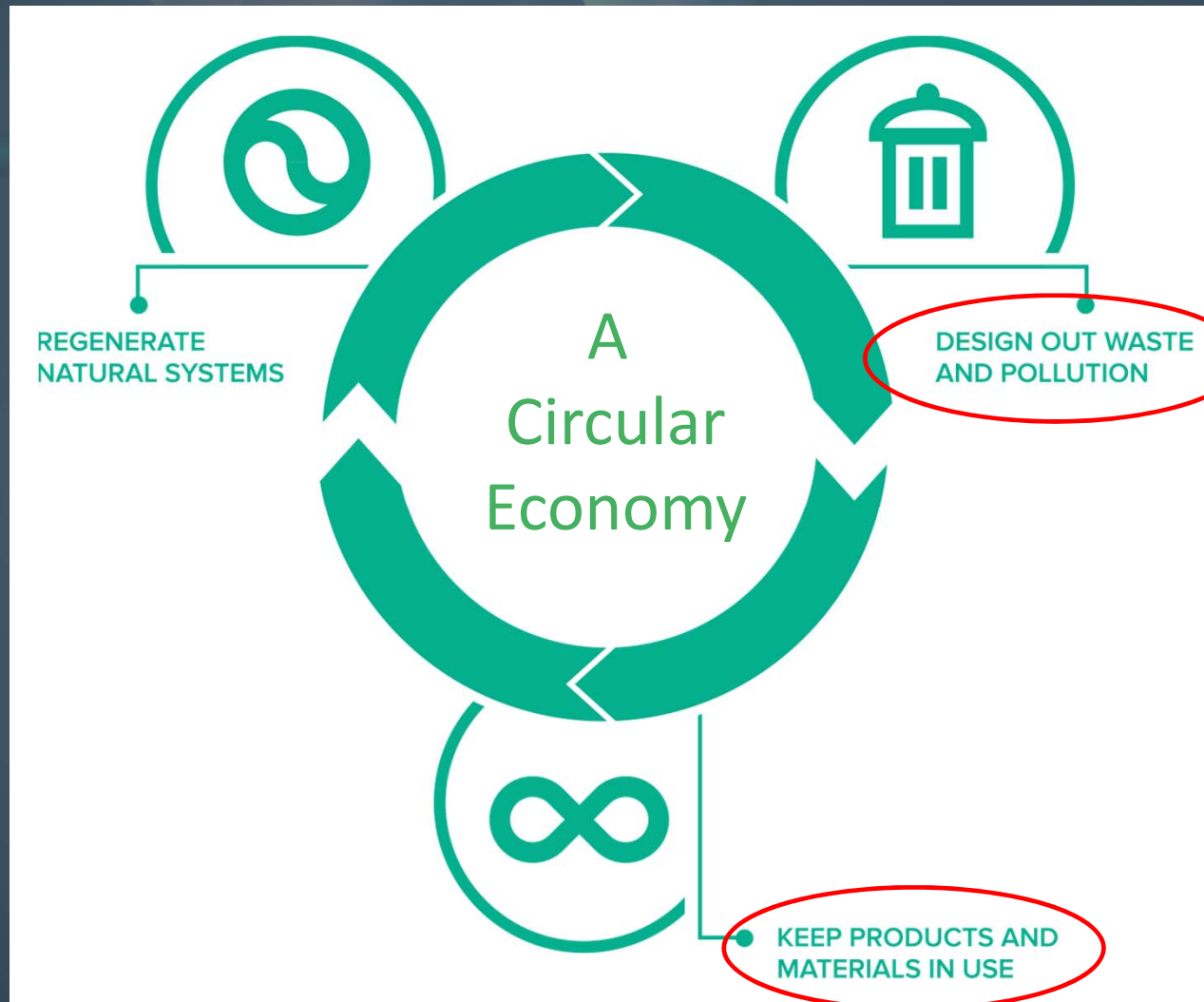
Italy has a nice circular diagram for foundries



<https://www.assofond.it/en/foundries-and-circular-economy>



# 3 high level principles of a circular economy



<https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy>

‘Keep products and materials in use’







New alloys

Manufacturing innovation

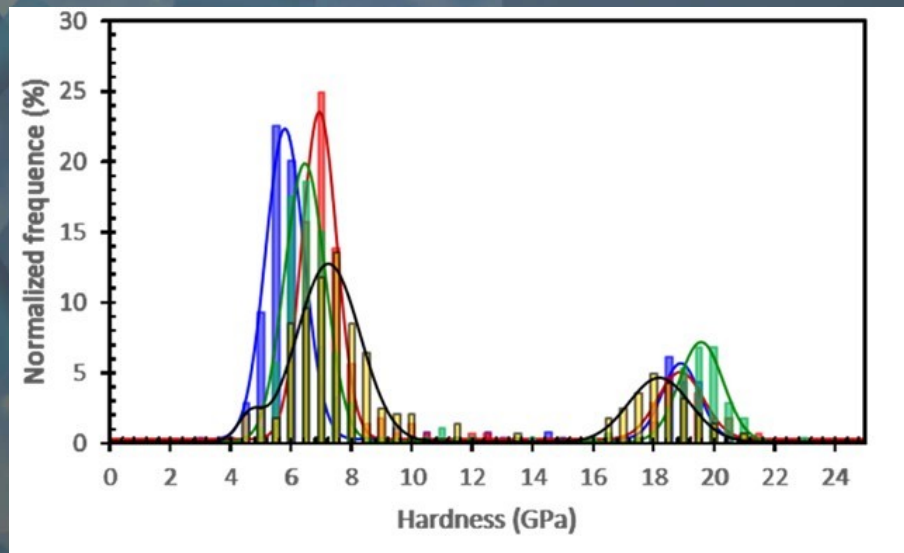
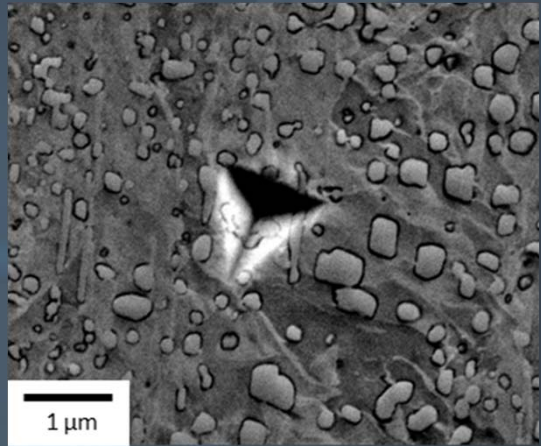
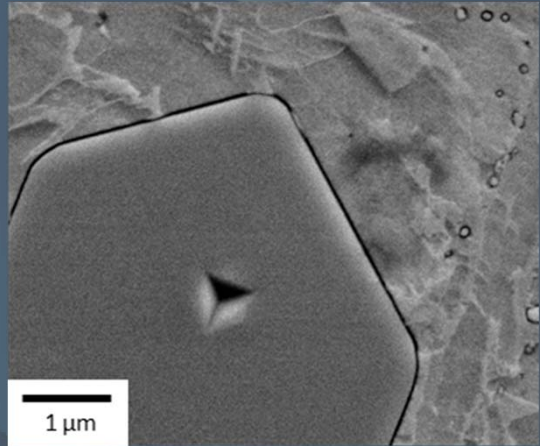
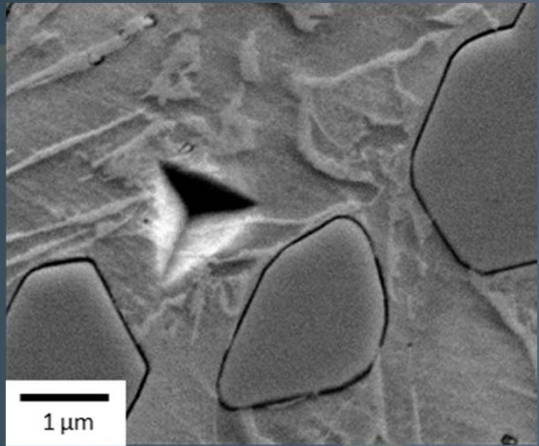
Modelling and systems



**WEAR RESISTANCE**



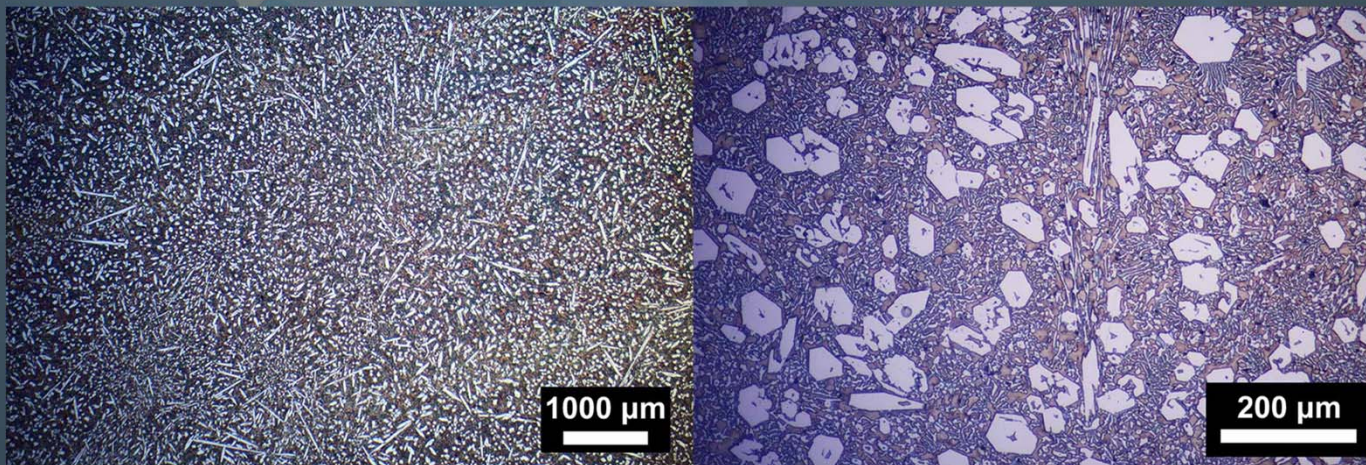
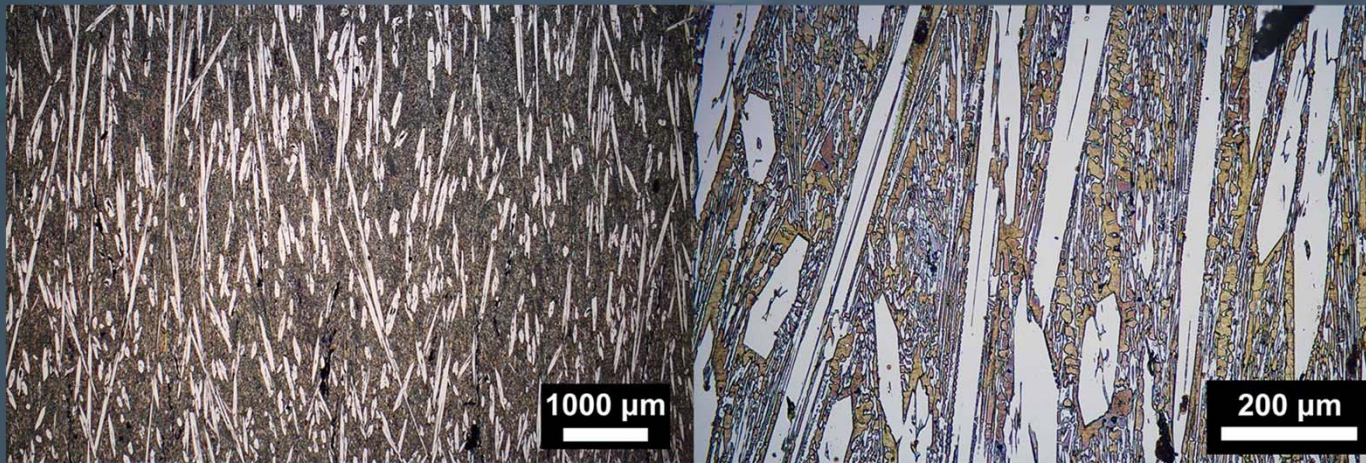
# Understanding hardening contributions and sensitivity to heat treatment





# Grain refining to help with toughness

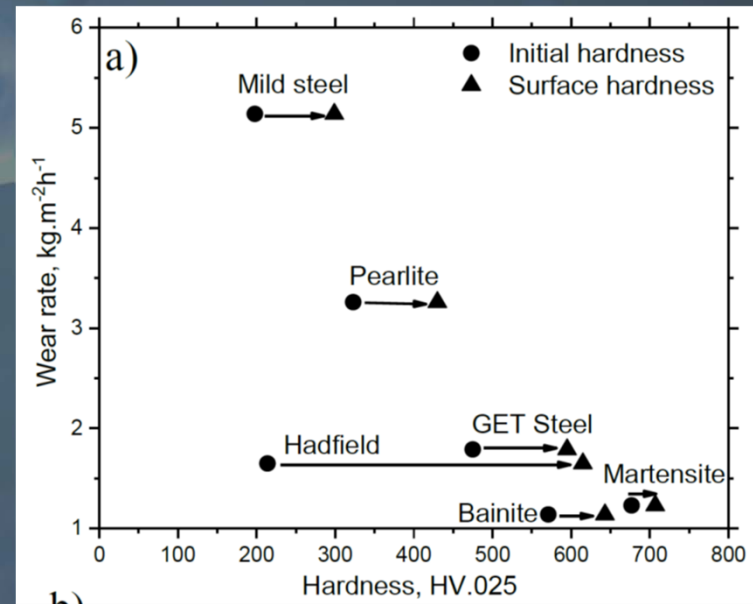
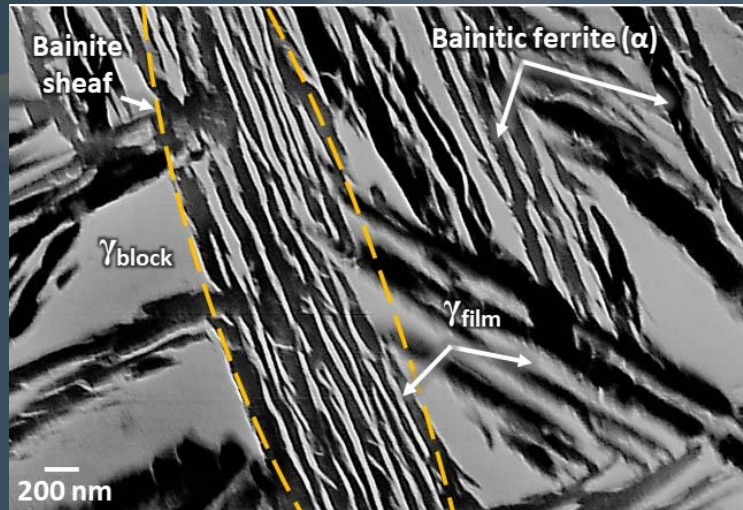
No modifier



Modifier added



# Nano-bainite in mining applications?

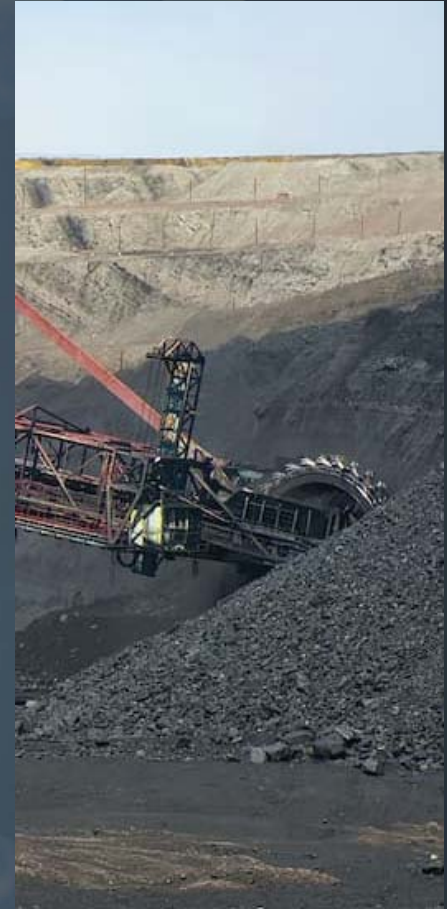


# Wear material challenge



?

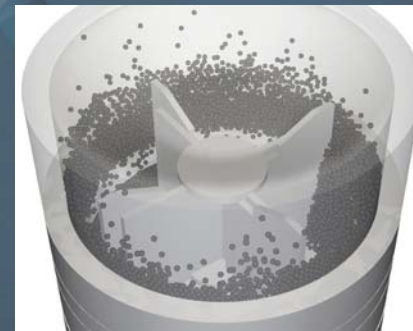
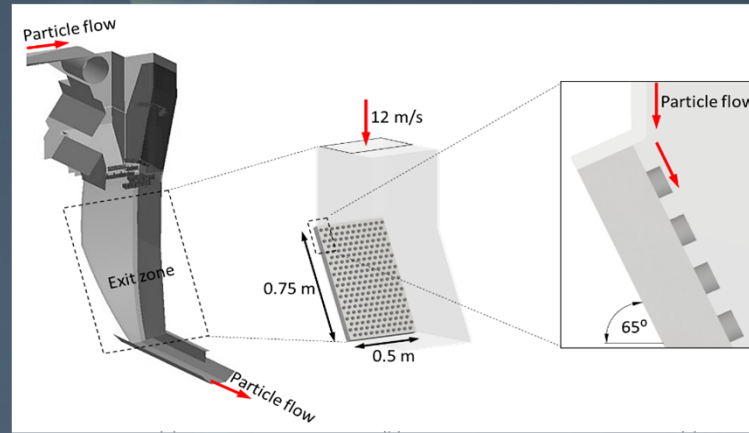
?



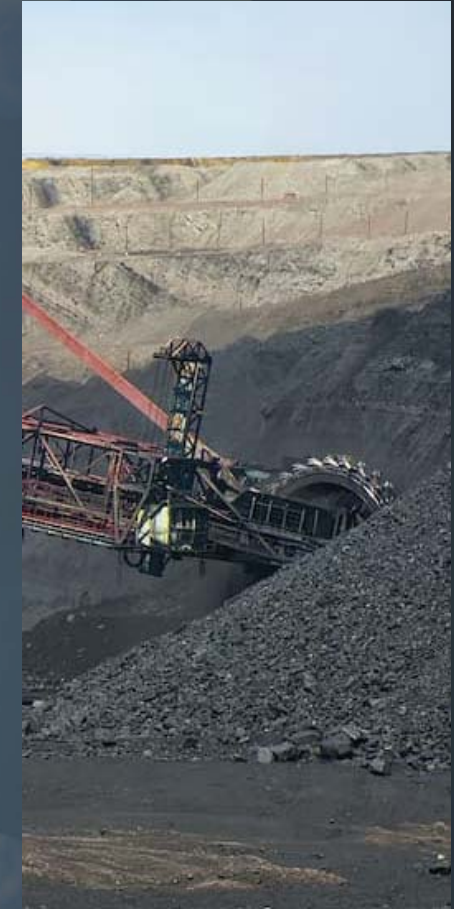


# Wear material challenge

# model processes

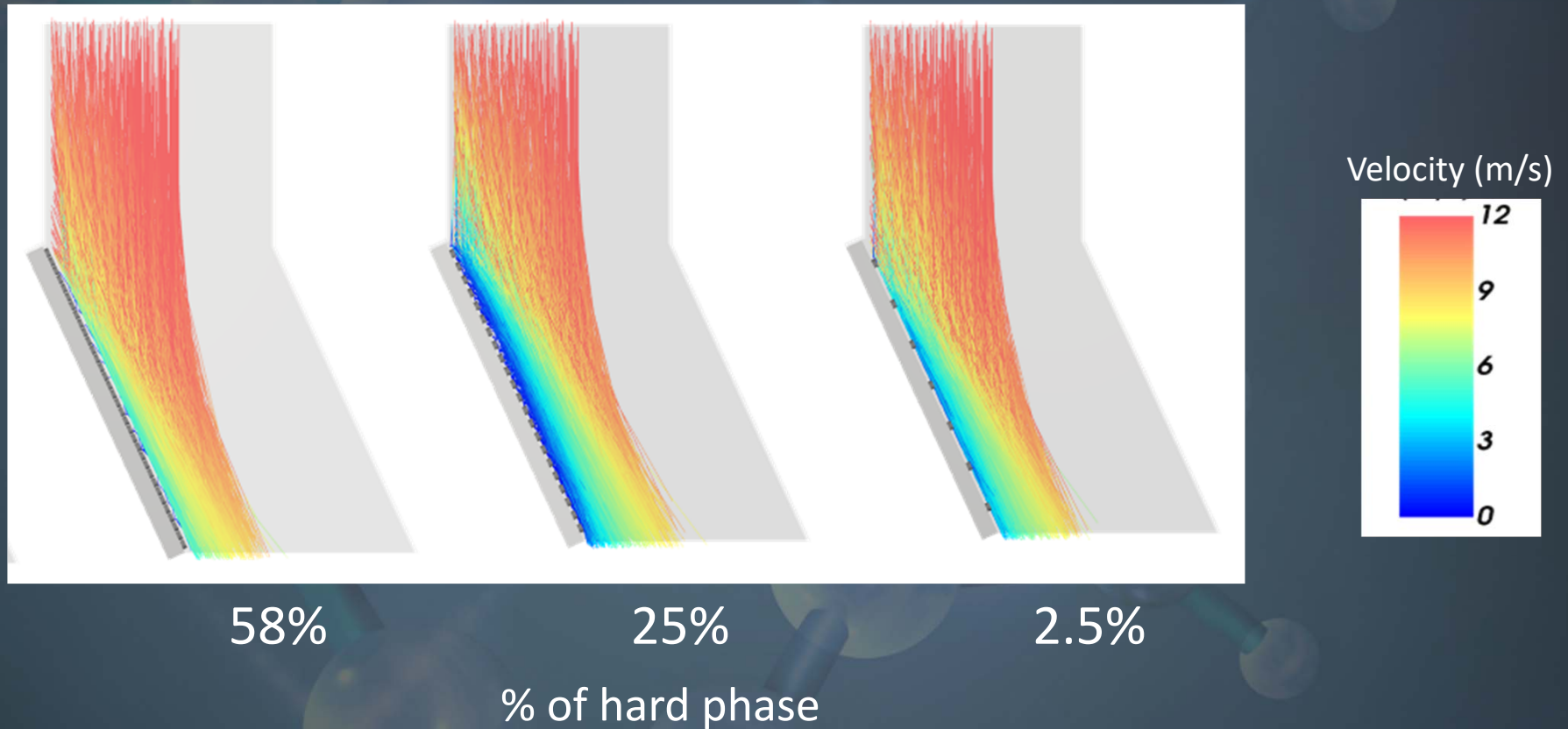


# model tests

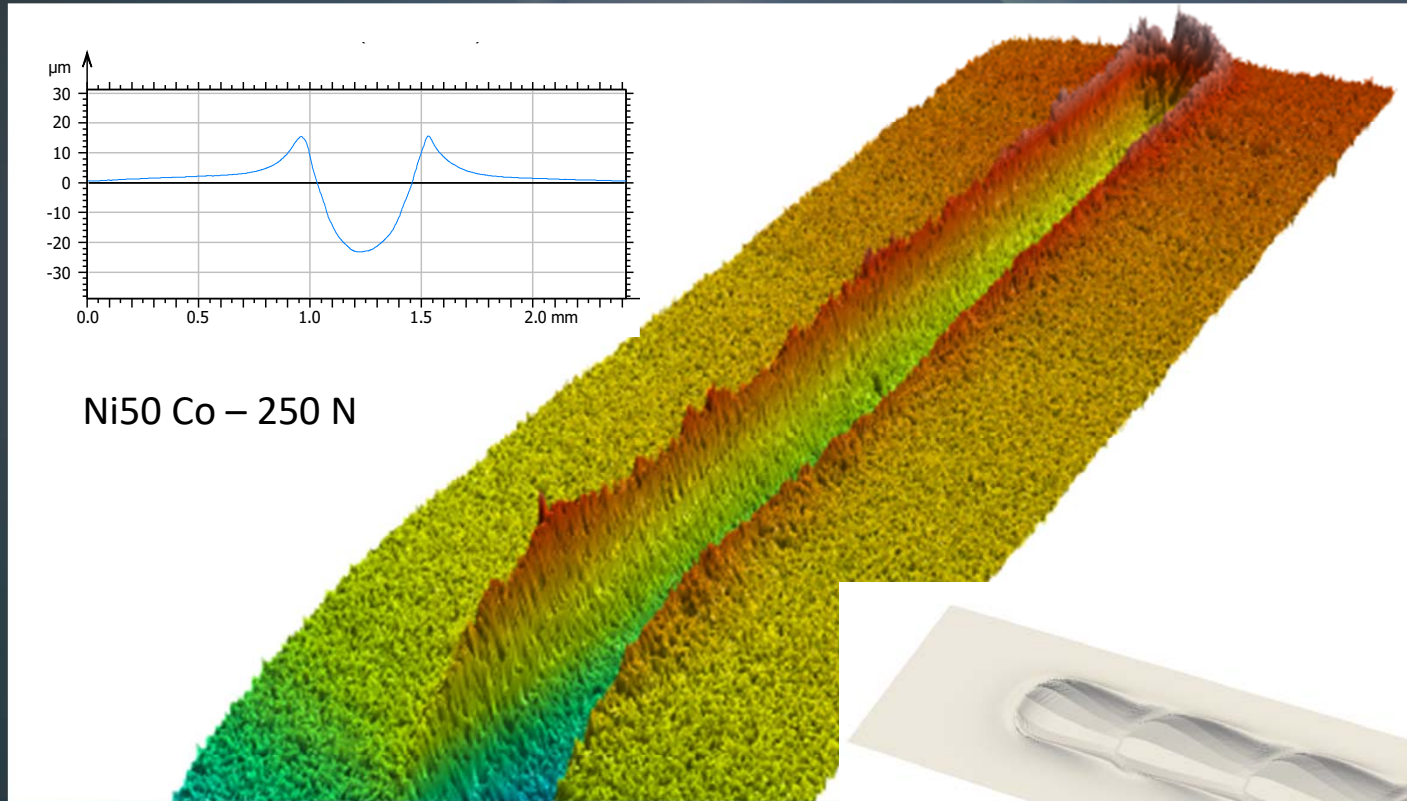




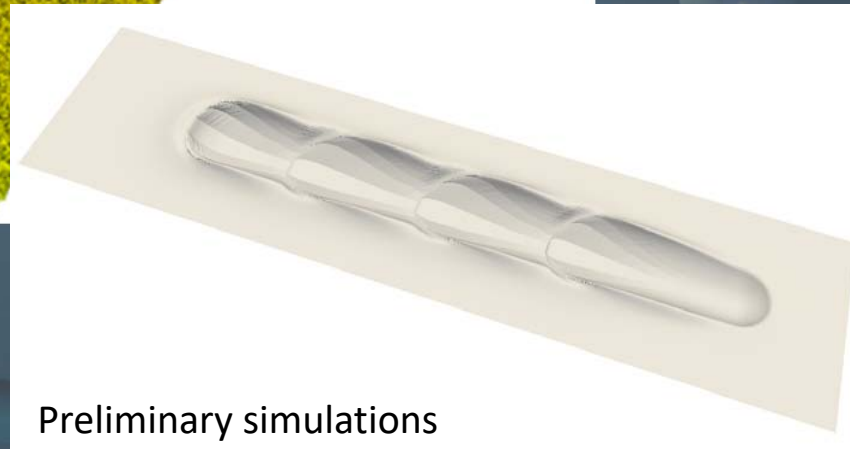
# Modelling particle flows in a chute – impinging on a plate reinforced with a hard phase



# Understand the elementary process: in gouging wear – the scratch



Ni50 Co – 250 N



Preliminary simulations



# Studying model Co-Ni model alloys via fast additive manufacture of followed by hammer peening and scratching

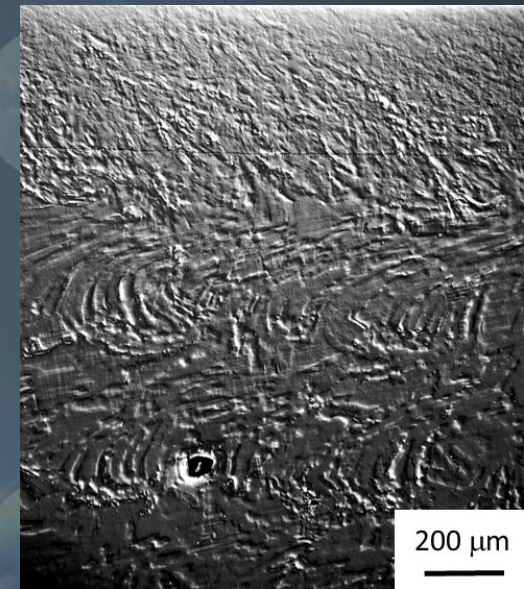


As-deposited Ni-Co alloys



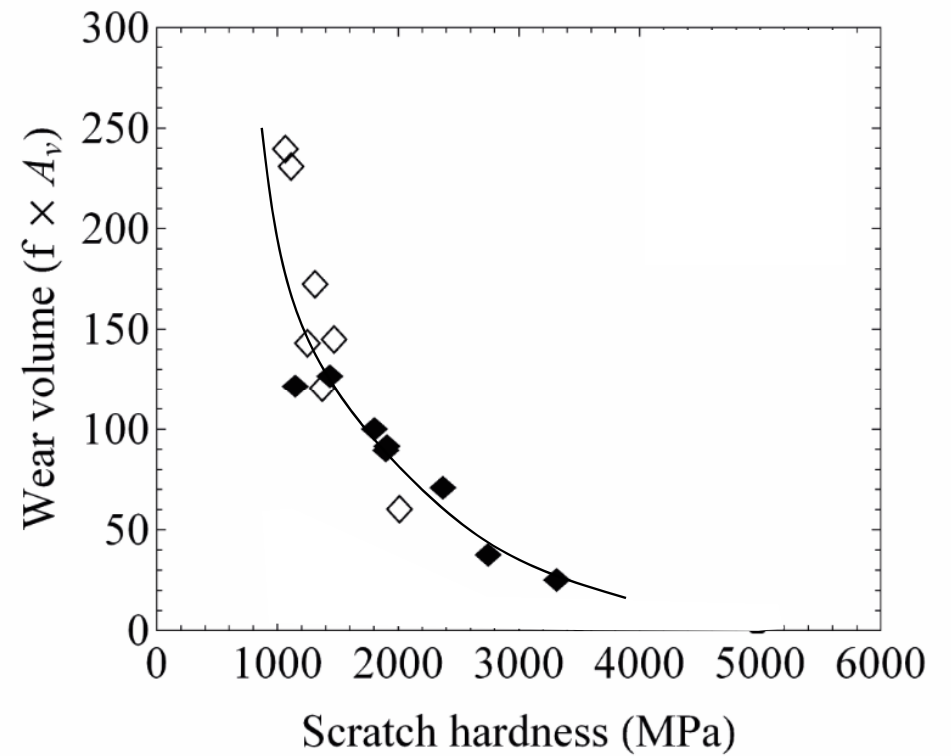
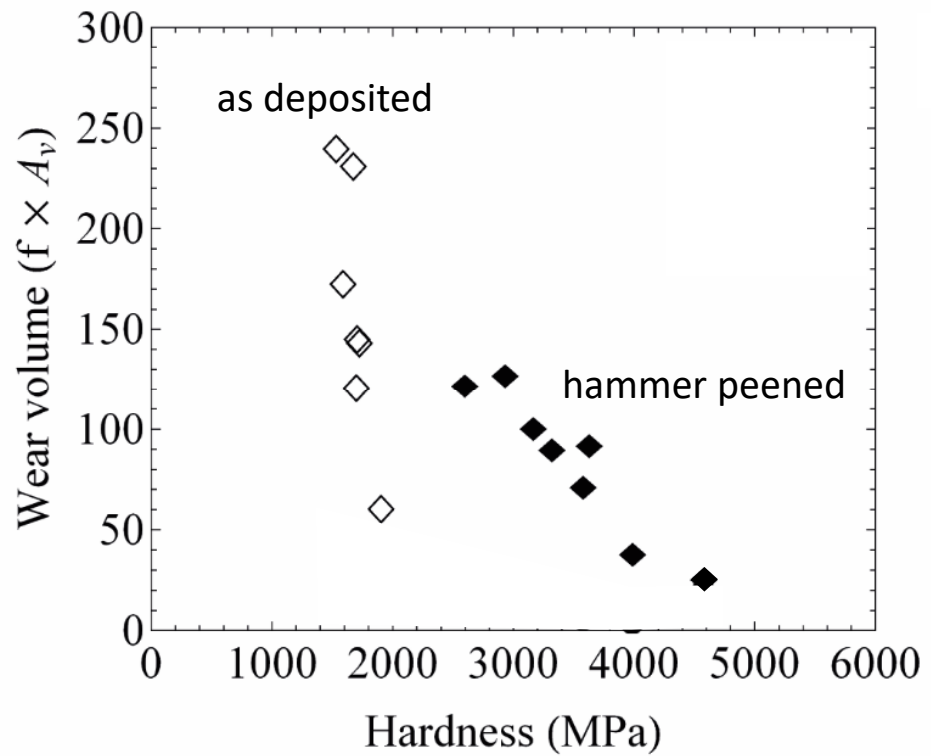
Hammer peened samples

Hammer peened surface



Cross section microstructure

# Correlating hardness with wear – need to focus on scratch hardness





“Design out waste and pollution”

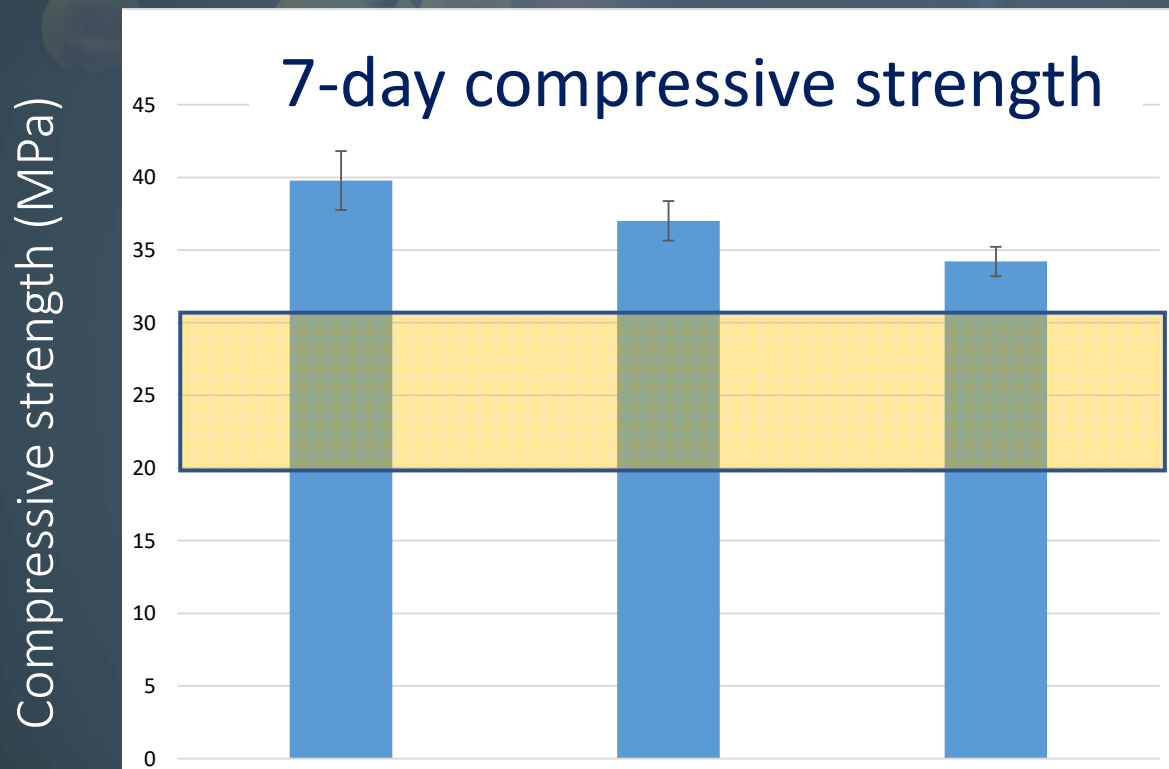






# Turning PFAS affected soils into concretes via heat treatment

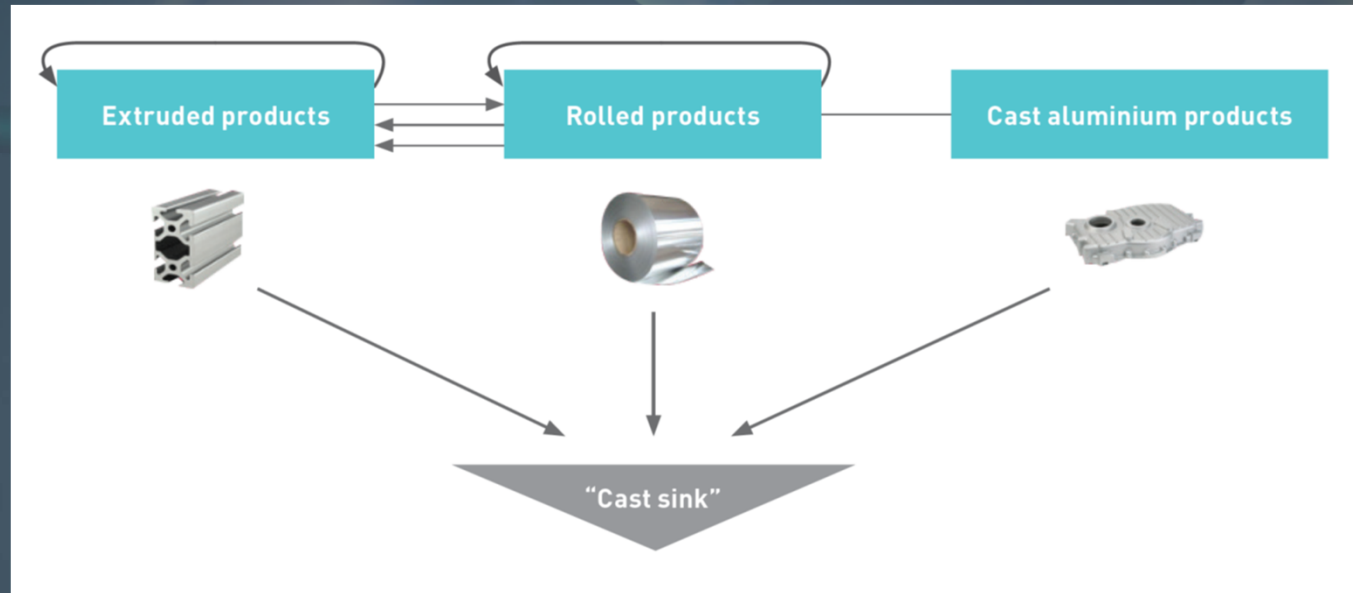
ARC funded collaboration with RENEX Group OpCo PTY LTD & The Remediation Group PTY LTD



Moderate strength structural grades e.g. foundations

Reference    ~33% ex-PFAS soil (-100% fines)    ~35% ex-PFAS soil (-13% cement)

# European Aluminium – Circular Aluminium Action Plan (2020)



Report points to the need for:

- Improved separation processes and technologies
- New 'recycling-friendly' alloys

# Seeking alloy equivalents to 'bubble and squeak'

Desire a base recipe that tastes great and is consistent in flavour irrespective of the variation in ingredients





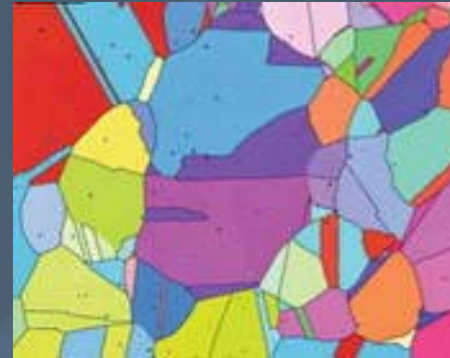
Complex alloys can be remarkably similar in structure  
these are the (fcc) 'high entropy alloys'



$\text{Fe}_{40}\text{Mn}_{40}\text{Co}_{10}\text{Cr}_{10}$



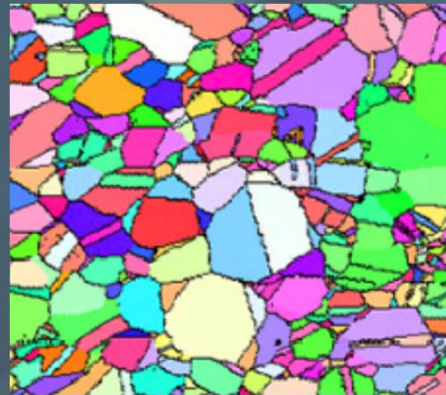
$\text{Fe}_{20}\text{Ni}_{20}\text{Co}_{20}\text{Cr}_{20}\text{Mn}_{20}\text{C}_{0.5}$



$\text{Mn}_{45}\text{Fe}_{37}\text{Co}_9\text{Cr}_9$



$\text{FeNiMnCr}_{18}$



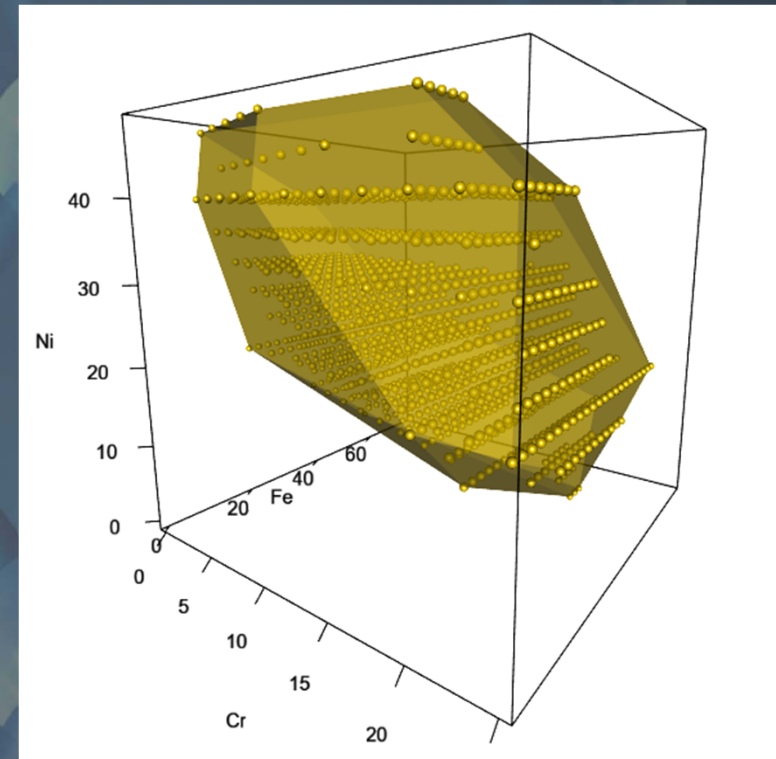
$\text{Fe}_{40}\text{Ni}_{25}\text{Cr}_{15}\text{Co}_{10}\text{V}_{10}$

Thanks to Nima Hagdadi

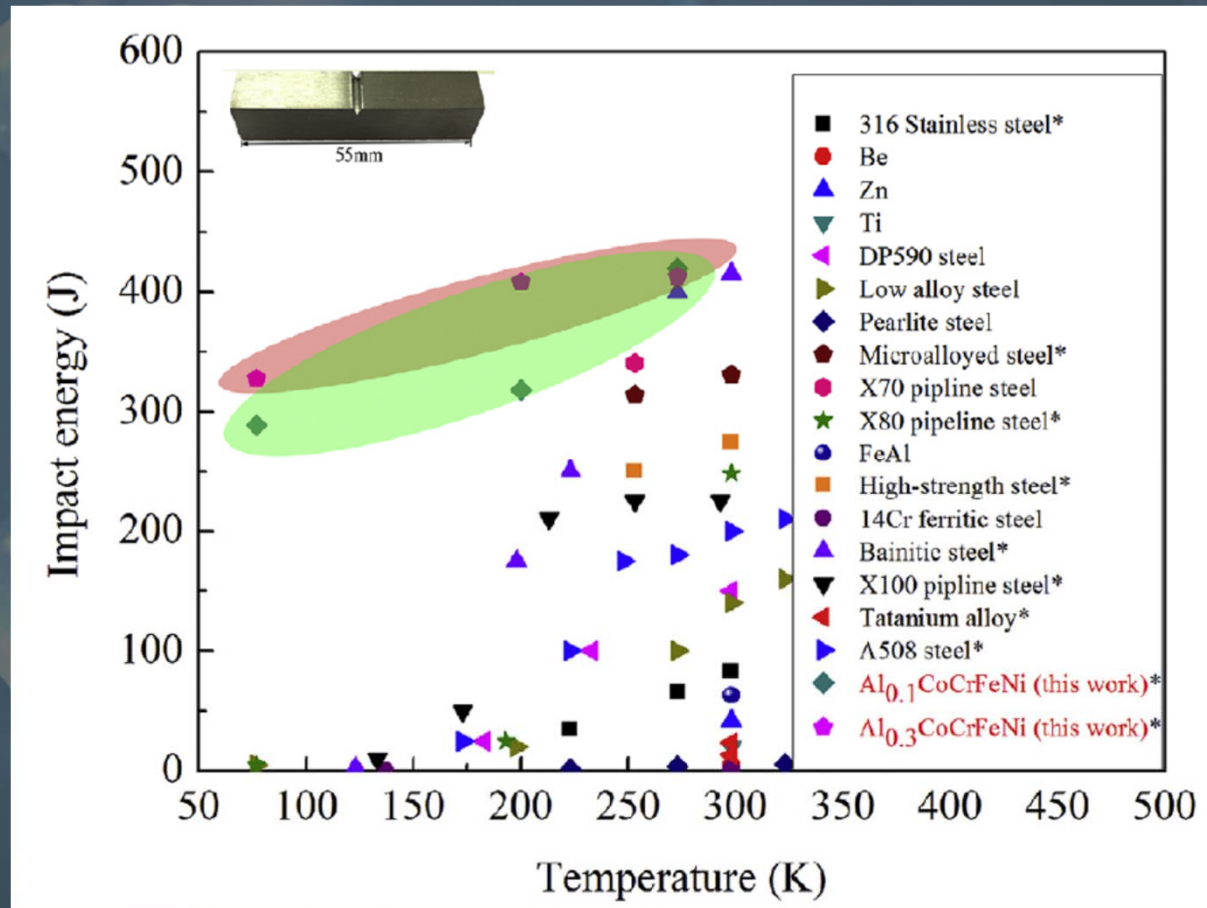
# 'Compositionally flexible alloys' a great place to send mixed recycling streams?



uk.emrgroup.com



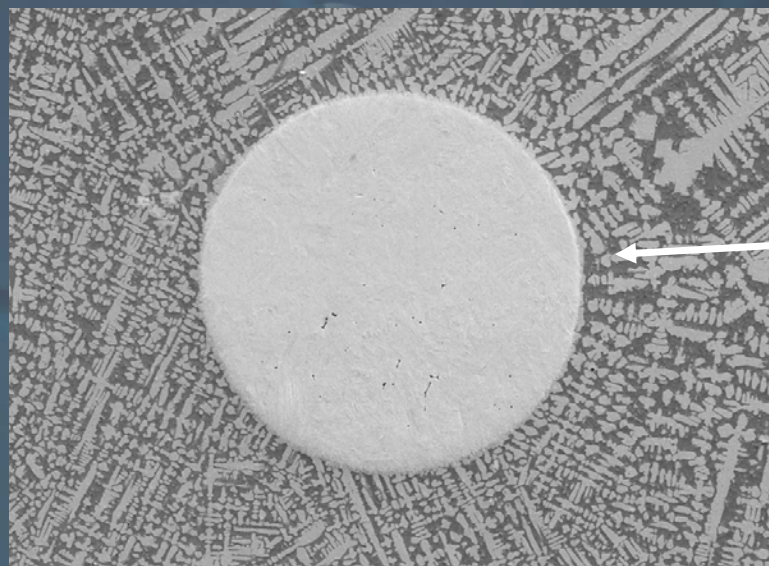
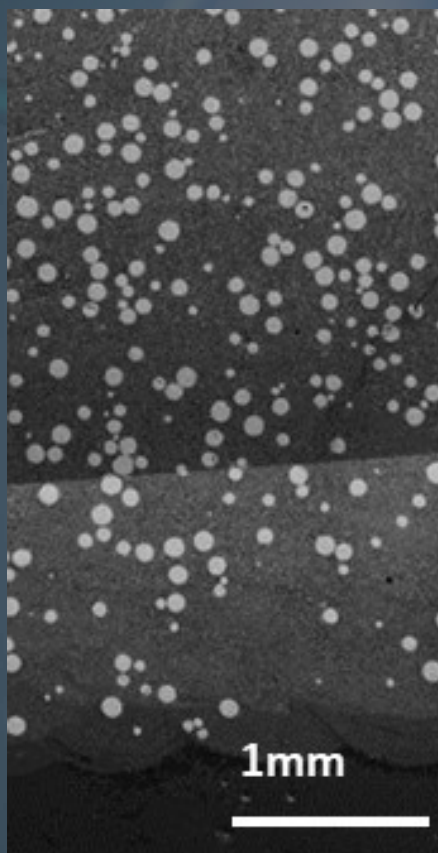
# Compositionally complex alloys can show very high toughness



Charpy impact energy of HEAs vs. other materials at the different temperatures (D.Y. Li et al, 2019)



# Complex, high entropy alloys for tough hard-facings from mixed scrap?

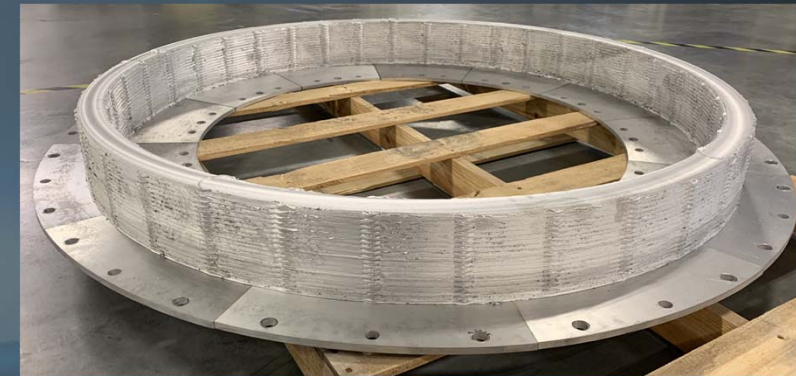
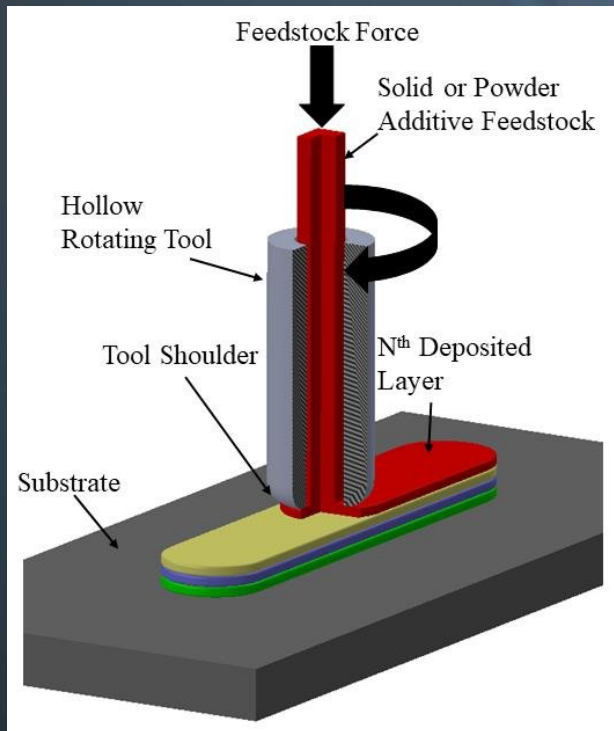


$HV_{20} = 732 \pm 31.5$

Laser deposited  $CoCrFeNiTi_{0.2at.}\%$  + 35 vol%  $WC/W_2C$

# New Processes? - Friction Stir Additive Deposition

Fast, big, near net shape additive manufacturing in the solid state (no melting)

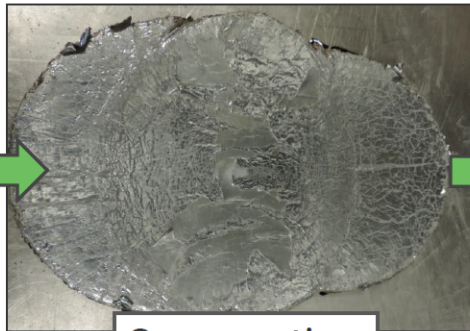




# Titanium Ti-6Al-4V



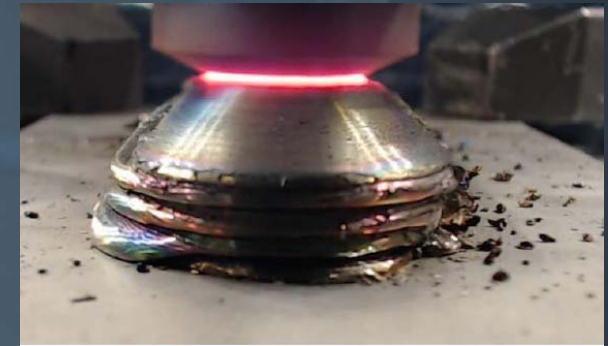
Ti64 Scrap



Compaction



Solid Filler Bars

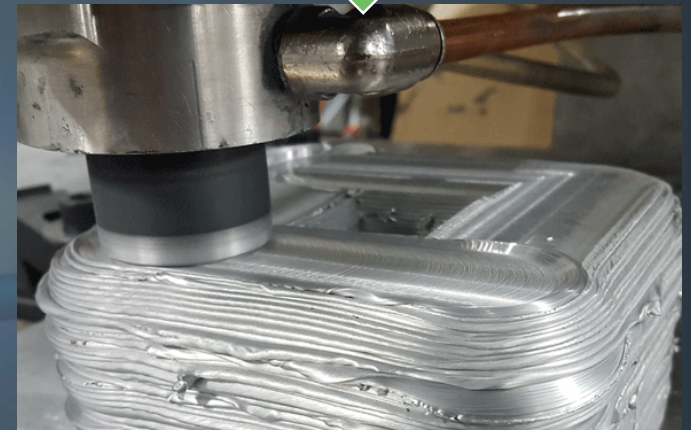
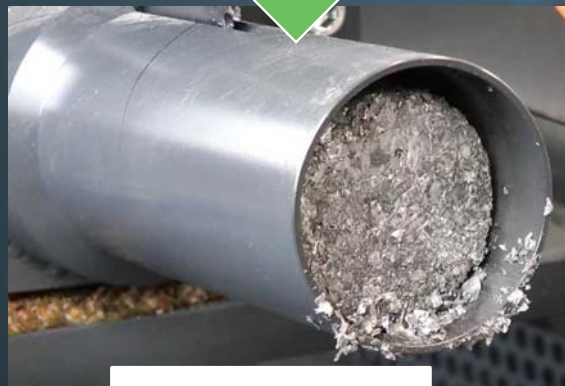
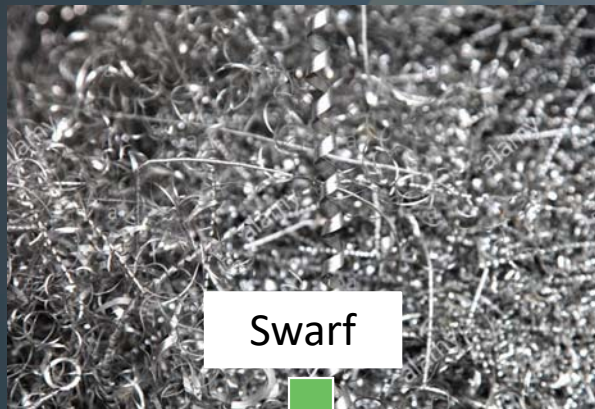


Deposition





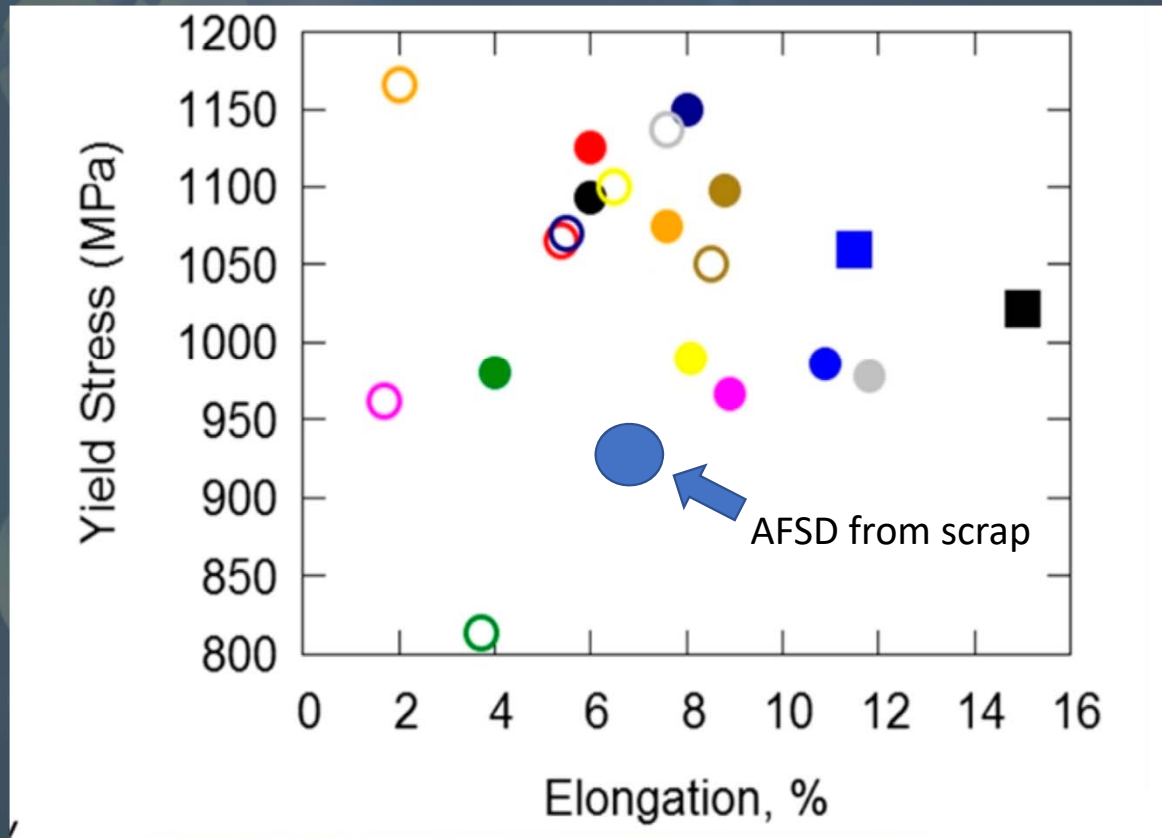
# Al 6XXX re-use



## Conclusion

Making manufacturing more circular will require technological, structural and behavioural change.

# Preliminary Ti-6Al-4V tensile properties for AFSD from scrap (compared SLM additive manufacturing)



SLM data from Agius et al. A Review of the As-Built SLM Ti-6Al-4V Mechanical Properties towards Achieving Fatigue Resistant Designs Metals 2018, 8, 75; doi:10.3390/met8010075



# Entry to Expand – BHP (Chile) Tailings Challenge

One of many “Tailings Challenges” underway worldwide  
Re-thinking mining and seeking to remove tailings dams from landscapes.

